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THE LARGE AREA CROP INVENTORY EXPERIMENT

An experiment to demonstrate how space-age technology can contribute to solving critical problems here on earth

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LARGE AREA CROP INVENTORY EXPERIMENT
LACIE

SPACE AND LIFE SCIENCES DIRECTORATE
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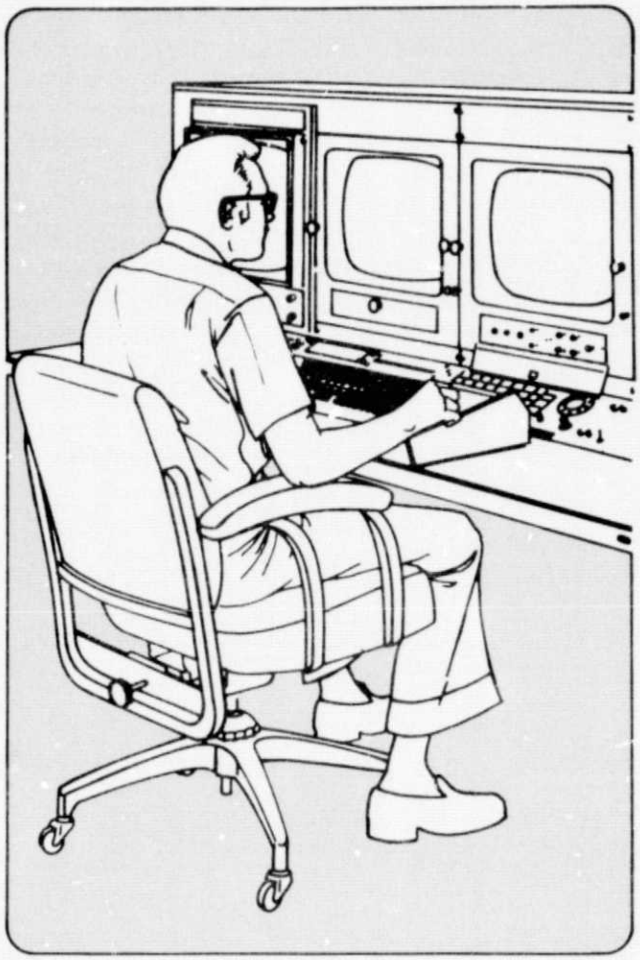
LACIE — Large Area Crop Inventory Experiment . . . Background

1959	Agrobusiness expresses interest in mapping stressed vegetation to National Research Council (NRC) of the United States.
1960	NRC assigns committee to investigate potential of remote sensing in agriculture
1961-64	Development of new remote sensors (multispectral scanners) and feasibility studies for their applications
1965	Research program established to apply remote sensing in agriculture
1966	First computer-aided classification of wheat and other crops using airborne multispectral scanner data
1968	Early efforts to develop weather-based crop yield models
1969	Apollo multiband camera experiment (SO65) simulating Landsat bands, computer processed to identify wheat and other crops
1971	Corn blight watch experiment, first agricultural large area effort. Used both image analysis and computer-aided analysis of airborne multispectral scanner data
1972	Landsat 1 launched — Joint NASA-USDA (ASCS) Landsat-1 investigation at Houston — other Landsat-1 investigations
1973	Joint United States-Canadian study of agriculture using Landsat data
Sept. 1974	LACIE tri-agency project officially authorized

Introduction



Can you visualize a space-age system that uses pictures taken from satellites to predict crop production? At the push of a button, accurate forecasts of crop production for any wheat producing area of the world would roll out of a computer.

It doesn't happen that way today, but systems that will make it possible are being developed. The new systems will use pictures similar to those from weather satellites that we see on T.V. news programs. However, the pictures that will be used to estimate crop production will be much more detailed than the weather satellite pictures.

Scientists from three major U.S. agencies are now cooperating in a project to test the technology that would be used in a satellite-aided crop production estimating system. The three agencies are the U.S. Department of Agriculture (USDA), the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce, and the National Aeronautics and Space Administration (NASA). The project is called the Large Area Crop Inventory Experiment (LACIE). It is an experiment to demonstrate how space-age technology can contribute to solving practical problems of agricultural management.

This booklet will describe the why, what, who, how, when, and future applications of LACIE.

The Why of LACIE

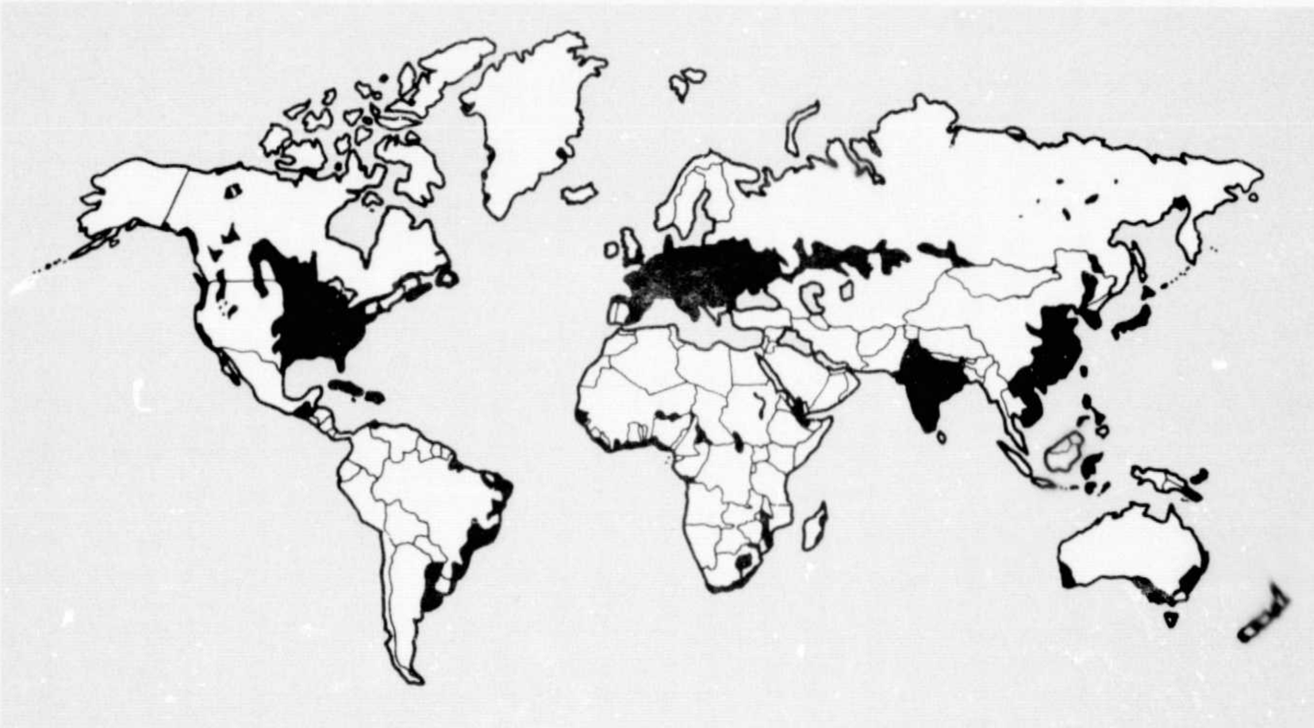
For many centuries mankind has depended upon the practice of agriculture in some way or another for food and fiber, and the food supply for those who practiced farming generally improved.

In some parts of the world, farmers utilizing modern agricultural techniques often produce a surplus of food products, while in other areas food shortages still result in hardship for the populace.

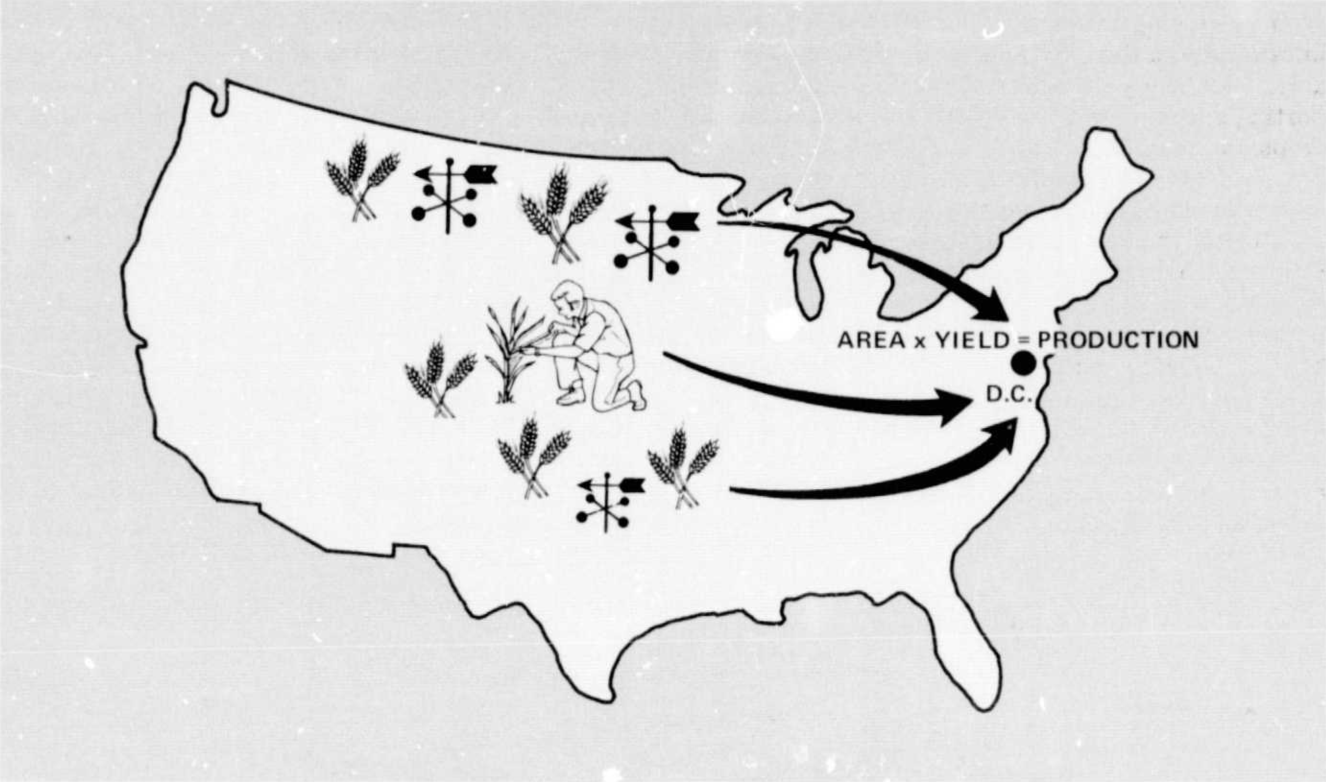
Accurate crop production estimates, a global flow of information about factors related to and influencing crop production, and an efficient produce distribution system are needed to balance global supply and demand for food and feed grains.

The United States is a major producer of surplus commodity items and strives to improve the balance in world food supply and demand. By applying many of the aerial survey techniques and associated ground-based data systems developed for the space program, it can provide advance knowledge of crop production and potential demand. With this knowledge, food importers and exporters would be in a position to make earlier and more optimal decisions to buy or sell.

Concerning the need for developing space-age crop monitoring techniques, a spokesman for USDA said, "The gathering of accurate crop production



Population growth puts increasing pressure for more crop production on the major arable land areas of the world depicted by the shaded regions above.



A network of field observers and weather stations in wheat growing areas of the United States produces very reliable information for national wheat production estimates. However, field reports are not available from most other wheat growing areas, and production estimates for areas outside the United States are not always reliable.

information is becoming increasingly important to the United States and the world, particularly in regard to our nation's expanding capacity for exporting feed and food grains."[1]

Another USDA official told the U.S. Congress, "To permit rational decisions in areas such as production, marketing, transportation, and internal trade, we must have up-to-date, accurate information on world food supplies and world food needs. The Department of Agriculture has been assigned the responsibility for collecting and reporting crop production information to the public."[2]

The current USDA crop reporting system in the United States involves many trained observers. They inspect crops in the fields and send the results through an automated reporting system that combines the information and computes the production forecasts. The USDA does have a good working relationship with many foreign departments of agriculture; however, from some countries, reliable

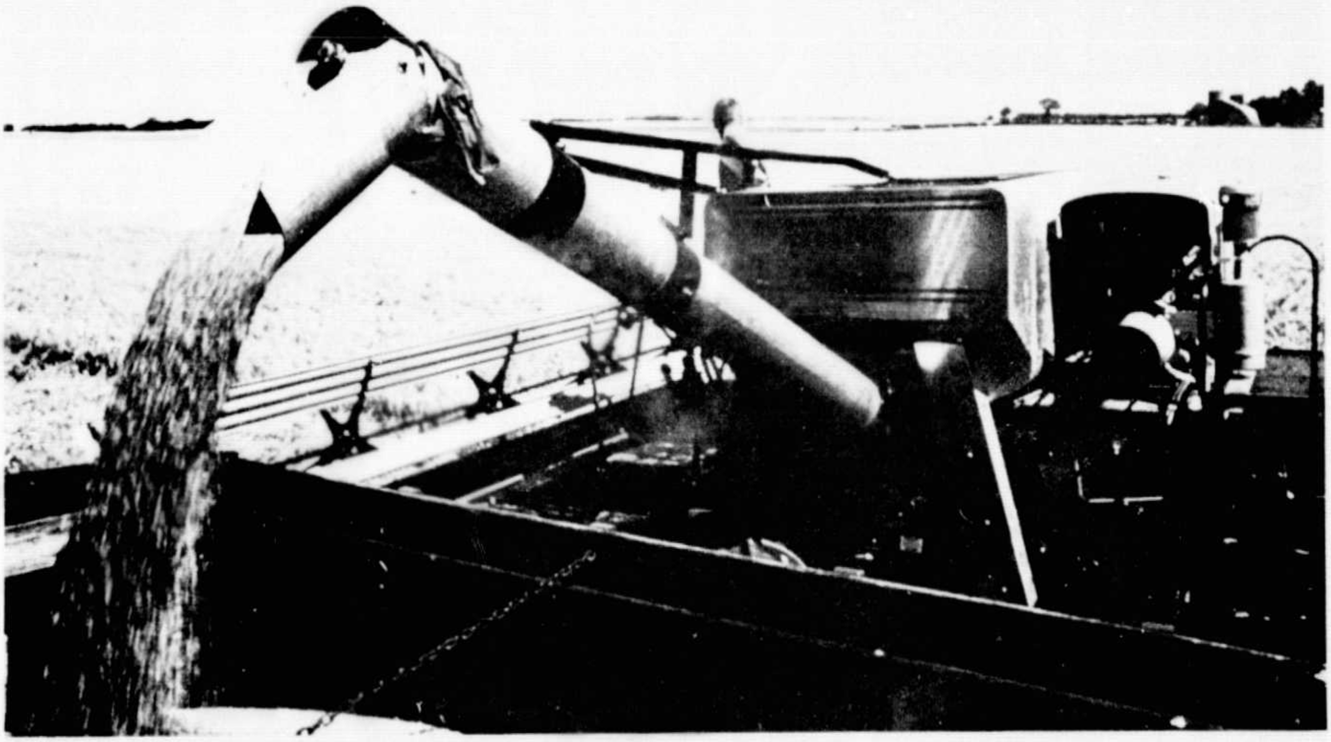
(1) From a public announcement by Dr. William L. Ruble, who was then Deputy Administrator, Management, Agricultural Stabilization and Conservation Service, USDA, at the ERTS-B press briefing, Jan. 14, 1975.

(2) From a presentation by Clayton K. Yeutter, who was then Assistant Secretary for International Affairs and Commodity Programs, USDA, to the Committee on Science and Technology, U.S. House of Representatives, Feb. 4, 1975.

crop producing information is difficult to obtain; in other areas, the crop data are completely unavailable. Not many other countries have adequate reporting systems, and the quality of information on crops varies widely from one country to another.

In the United States, and the few other countries with good reporting networks, accurate and timely crop production forecasts are available. In some other countries, however, crop information is either not known or is not made available to others. Lack of crop forecasts leads to planting, buying, selling, import, or export, decisions being made on the basis of incomplete information. Consequently, uninformed decisions result in hard-to-manage shortages for some and surpluses for others, less than maximum food production, and unrealistic food prices.

The techniques being tested by LACIE have the potential to provide worldwide crop forecasts. The LACIE activities were briefly described by former U.S. Secretary of State Dr. Henry F. Kissinger in an announcement at the 1974 World Food Conference. "Our space, agriculture, and weather agencies will test advanced satellite techniques for surveying and forecasting important food crops. We will begin in North America and then broaden the project to other parts of the world. To supplement the World Meteorological Organization (WMO) on climate, we have begun our own analysis of the relationship between climate patterns and crop yields over a statistically significant period. This is a promising and potentially vital contribution to rational planning of global production."(3)



(3) From a speech by Henry F. Kissinger, who was then U.S. Secretary of State, in Rome, Italy, Nov. 4, 1974.

The What of LACIE

LACIE is a developmental project for the USDA. The LACIE investigators are trying to determine how much information can be obtained about crops from Earth-observing satellites and from weather observations. For purposes of the experiment, LACIE is restricted to the study of a single crop—wheat.

The use of Earth-observing satellites to gather data on agricultural and other resources is an economically important application of the branch of space technology called remote sensing. In simple terms, remote sensing is the use of instruments to get information about an object without the instruments being in close contact with the object. Aerial photography is a well-known type of remote sensing.

The Who of LACIE

Each of the three agencies of the U.S. government (USDA, NOAA, and NASA), that are jointly conducting LACIE, brings particular expertise to the experiment.

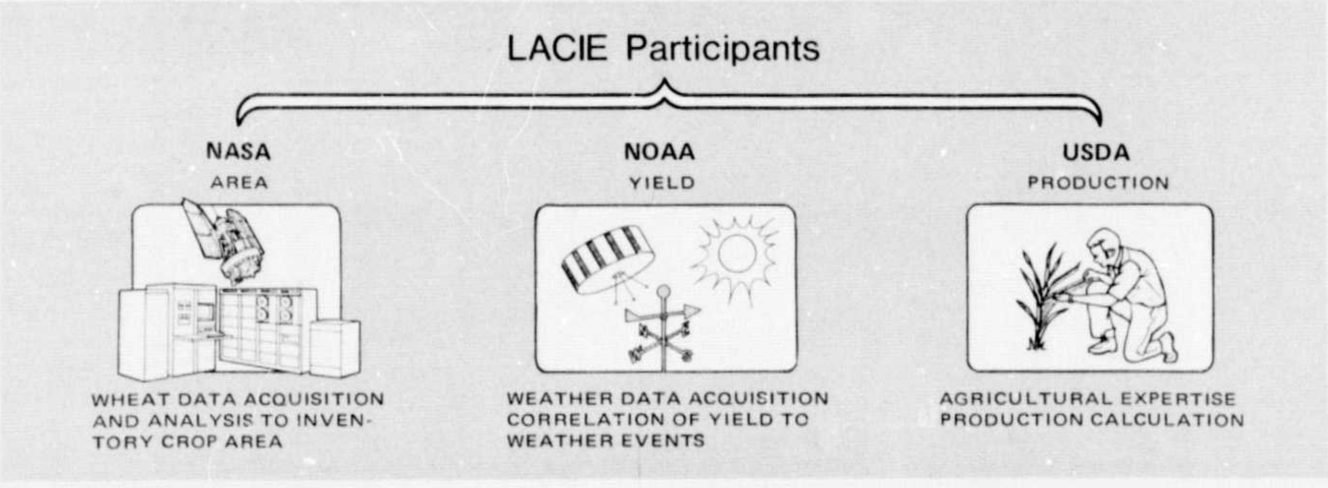
USDA

The USDA has responsibility for the agricultural programs of the U.S. government and requires worldwide crop information to carry out its duties. It has its own information-gathering systems in the United States and employs attachés abroad to keep abreast of crop conditions around the world.

The USDA has been using remote sensing techniques on a limited basis in the United States for about 40 years. It began in the 1930's with aerial photography. In the 1960's, it began using color infrared aerial photography for crop surveys and airborne thermal scanners to detect forest fires.

NOAA

NOAA has the responsibility for weather services in the United States and operates the National Weather Service which is primarily responsible for gathering weather data and issuing forecasts. It



Technological expertise of the three LACIE participants combine to satisfy the formula for estimating wheat production (Production = Area times Yield).

also operates the Environmental Data Service which maintains historical weather records for locations throughout the world and assesses the influence of climate on man's resources and his environment.

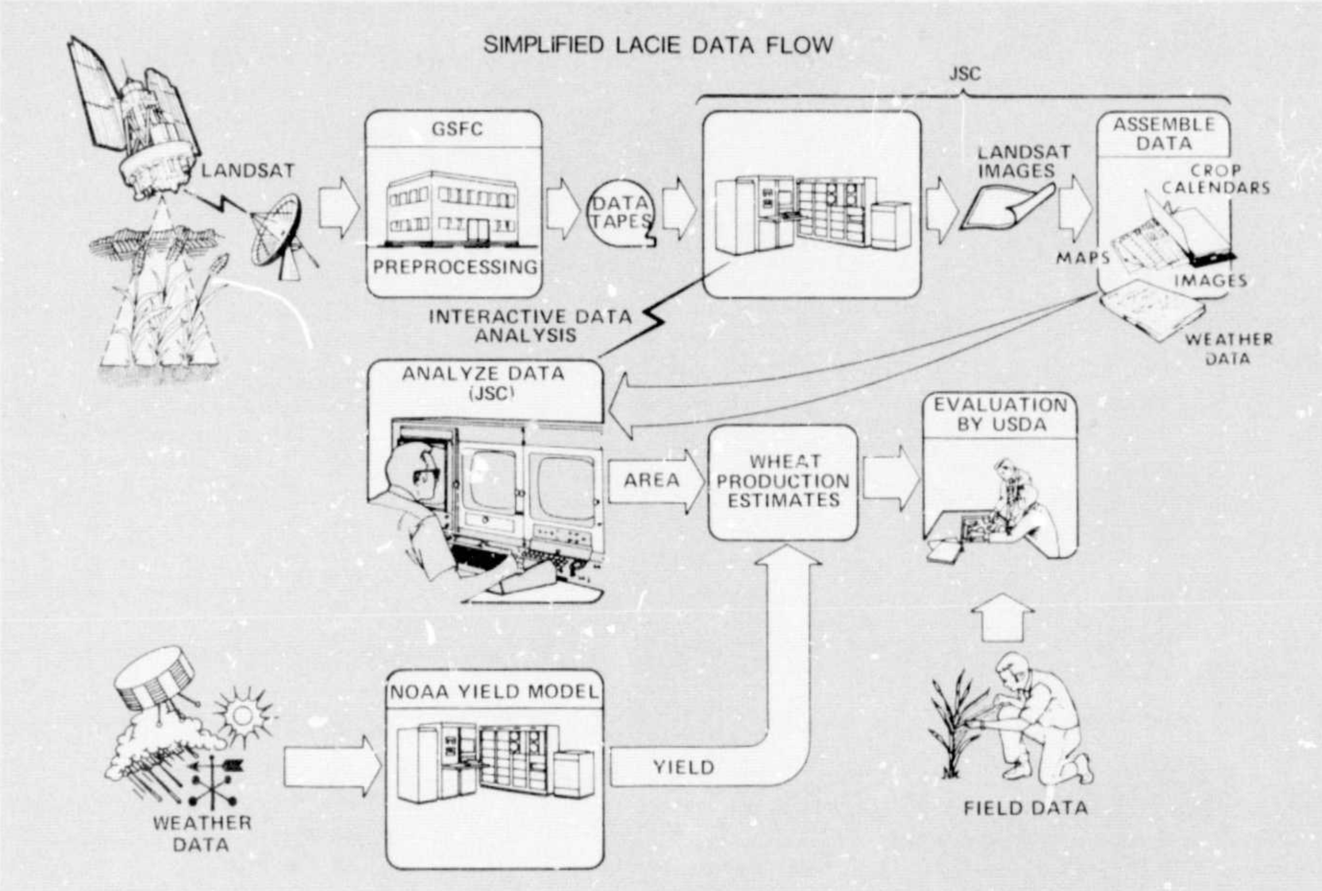
The relationship of weather conditions to crop yields has been the subject of special study by NOAA investigators. These agrometeorological models are used in LACIE to predict yield.

NASA

To most people, NASA means spaceflight and moon landing. However, an important part of the NASA charter has been to make space technology work for the benefit of people on Earth.

Of the many practical aspects of space technology, remote sensing has, perhaps, the greatest immediate potential to benefit mankind. NASA began developing remote sensing in the early 1960's during the Mercury manned spacecraft program. In 1969, a photographic experiment associated with the Apollo 9 flight produced data of interest in crop observations. In 1972, NASA launched the Land Satellite (Landsat 1), an unmanned, Earth-observing satellite specifically designed and equipped with remote sensing instruments for Earth resource observations. A series of remote sensing applications investigators confirmed that Landsat data could be used to accurately identify and measure a number of specific crops.

Dramatic photos returned from space heightened the awareness of our island earth and its thin and vulnerable biosphere.



A simplified schematic of LACIE shows the general data flow through major operations to produce production reports and to evaluate their accuracy.

LACIE is designed to use remote sensing technology to estimate production of wheat on a worldwide, country-by-country basis, with initial attention given to the United States as a test site.

In LACIE, production estimates are calculated for local areas and are aggregated to regional and national estimates.

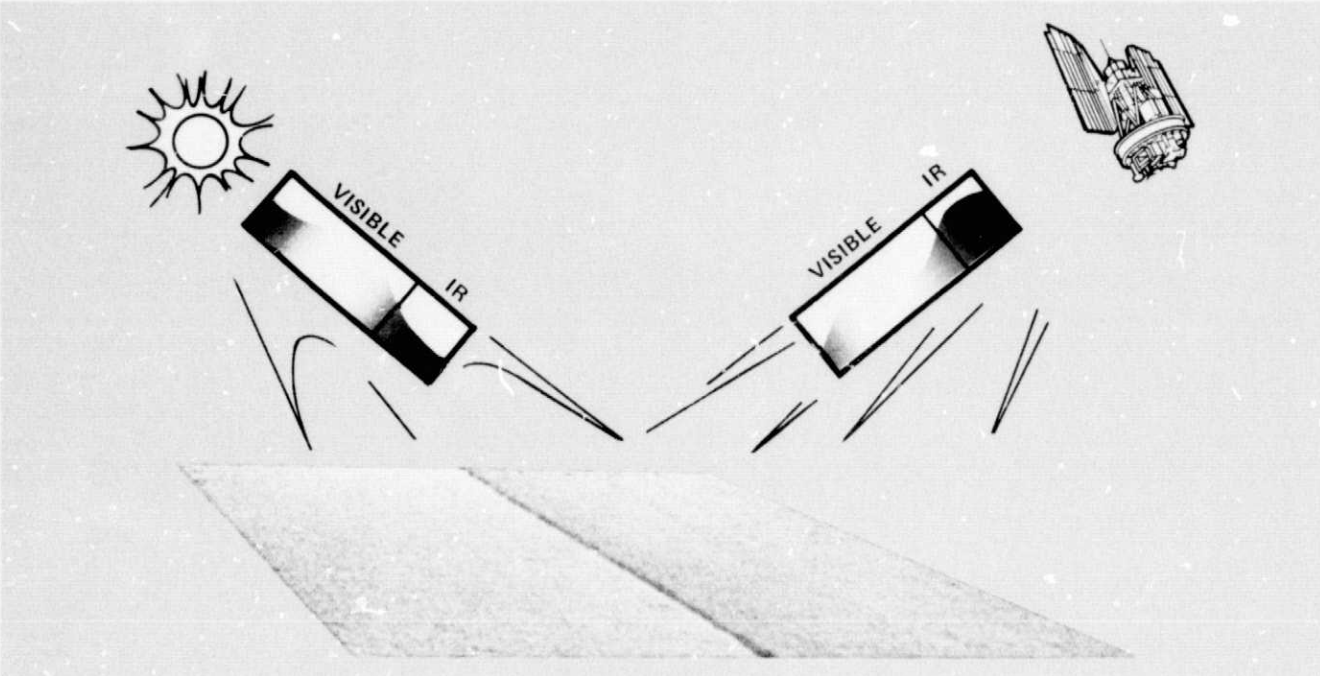
Wheat production estimates are made by multiplying the estimated area of wheat under cultivation by the anticipated yield per acre.

Wheat area estimates are derived by computer-aided analysis of images of selected wheat areas taken by Landsat.

Wheat yield per acre for LACIE is estimated from mathematical formulas based on the history of yield in specific areas. These formulas are called statistical models. They operate to predict yield on the basis of local precipitation and temperature during the current crop year.

A network of ground-based weather stations reporting to the WMO furnishes weather data used in the initial phases of LACIE. However, as the experiment progresses, data from NOAA environmental satellites may also be used to supplement the reports.

How LACIE uses Landsat Data



Each scene or object reflects a unique pattern of wavelengths called its spectral signature.

To arrive at wheat production estimates, analysts use highly automated computer processing to identify and measure wheat acreage in the Landsat scenes. Production from these acres are forecast using computer models which relate crop yield to current year growing conditions. Identification of the wheat crop in a Landsat scene is achieved by measuring, each 18 days, the amount of sunlight reflected from each field in the scene. Measurements from each acre are recorded using an electro-optical scanner orbiting aboard Landsat 500 miles above the earth. Because wheat vegetation reflects different amounts of visible and near infrared sunlight than do other crops, and because wheat grows and matures at a different rate, the temporal sequence of radiation measurements from wheat display a different temporal and spectral pattern than other crops grown in the same area. Once wheat is identified, as shown in the analysis classification map, its acreage is measured using the map.

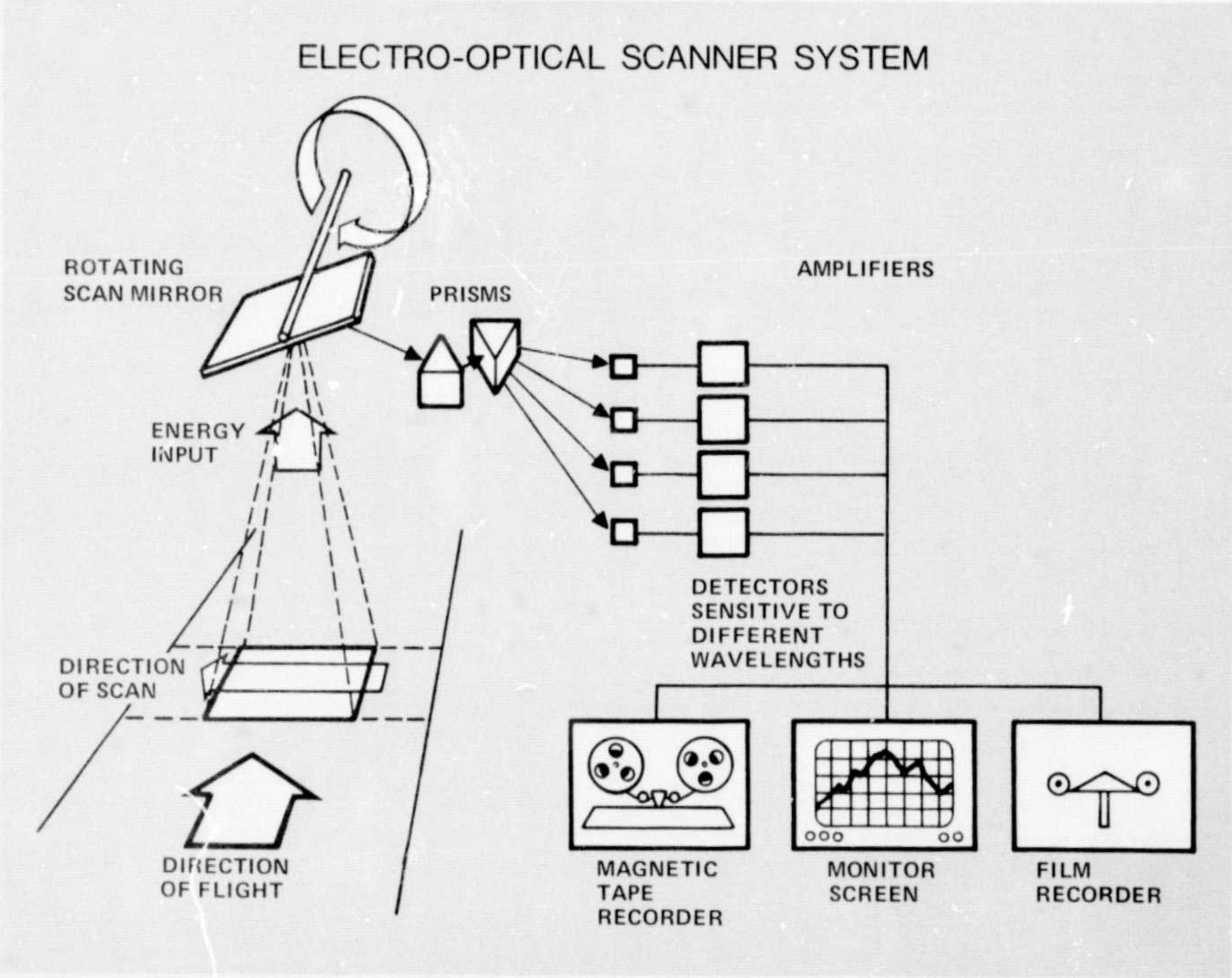
To ensure cost effective and accurate estimates, only about two percent of the Landsat scenes are analyzed on a probability sample basis. The acreage contained in the sample is selected to be representative of that in the entire region.

LACIE Results — Domestic

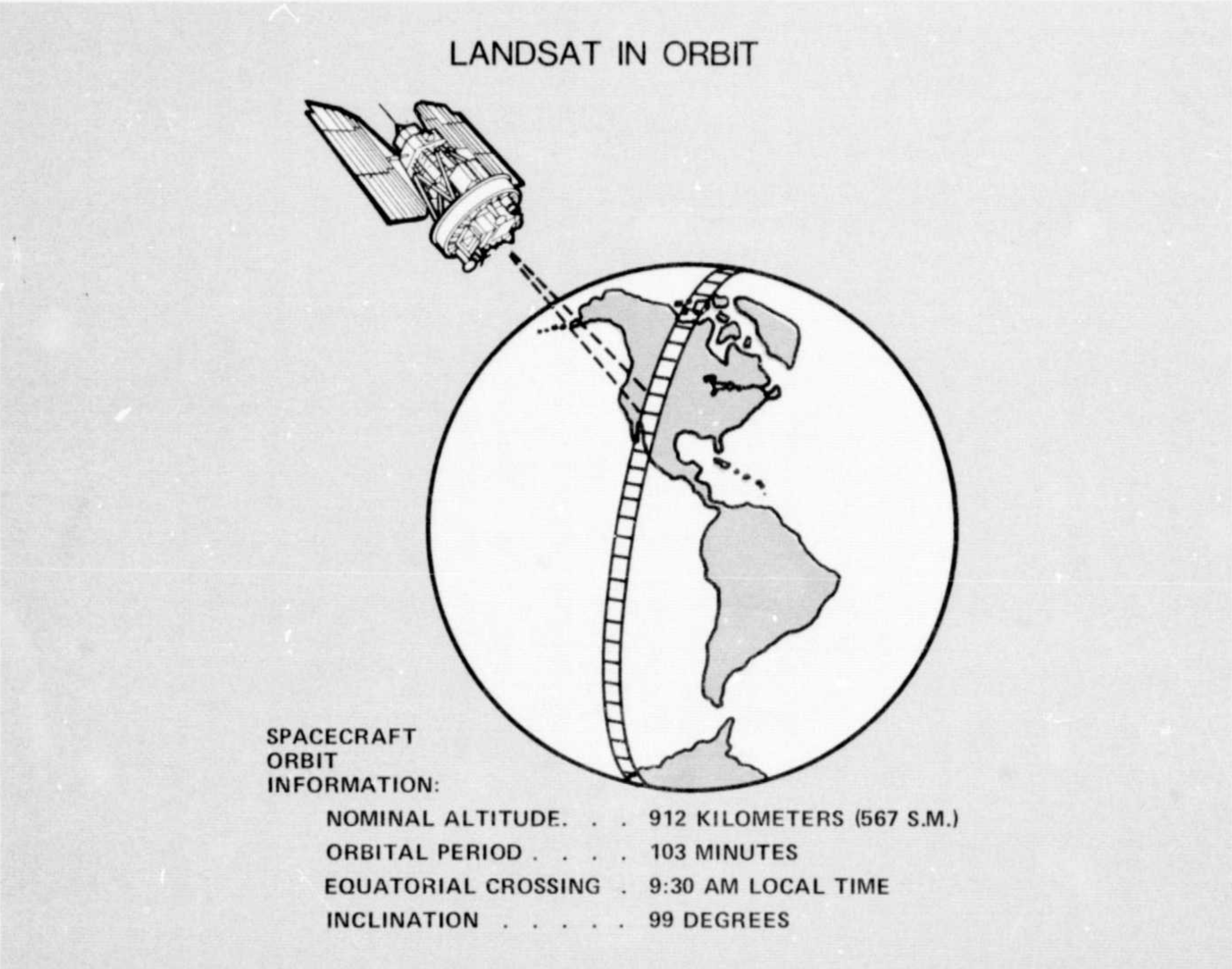
LACIE goals are to produce accurate, timely, and reliable wheat inventory information. Forecasts are made from planting through harvest. Two years experience with the LACIE analysis system indicates that accurate and timely crop production information with a known reliability can be obtained in both early season and at harvest using these techniques. These results, achieved with a technology

in its first generation of operation, are expected to produce even more accurate and timely forecasts as further research continues over the next several years.

Landsat uses an electro-optical system called a multispectral scanner, an instrument that records several individual channels or portions of the spectrum. It scans a swath of landscape and breaks up the electromagnetic energy it receives into separate bands or wavelengths by channeling them through optical prisms, beam splitters, and other diffractive devices. The separate channels or wavelengths are recorded as electronic signals rather than latent photograpnic images. The signals can be stored on magnetic tape, transmitted by radio, processed by a computer, or converted into T.V. or photographic images.

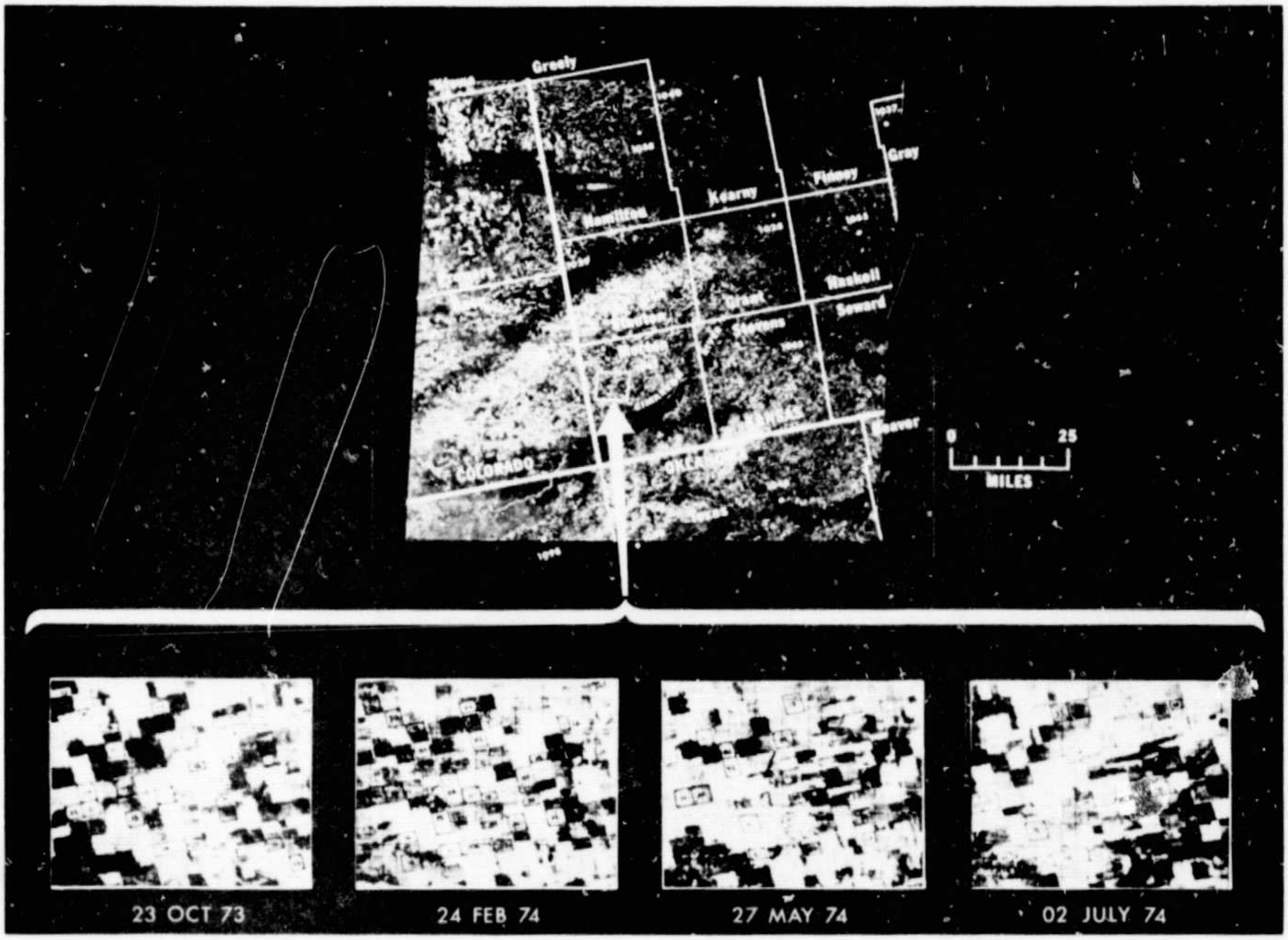


Schematic of a typical electro-optical scanning system.



The multispectral scanner aboard Landsat records images of selected wheat growing areas from which wheat area estimates are made.

To find the quantity of land planted in wheat, LACIE investigators use computer analysis of Landsat images. Selected wheat fields are used to calibrate the computer to recognize and measure wheat in each growing area. The computer procedure used in analyzing the Landsat images is called classification. These measurements, together with historical records of crop acreage, cropping practices, and planting trends enable the investigators to obtain an accurate evaluation of the total area of wheat crop that will be harvested. Since Landsat images may be taken throughout the growing season, such factors as winterkill of wheat, extreme drought, floods, and crop disease can be assessed for their effect.



The larger image above is a full frame Landsat image with an overlay to show geographic locations. The four smaller images are enlarged portions of Landsat images showing changes during the wheat growing season.

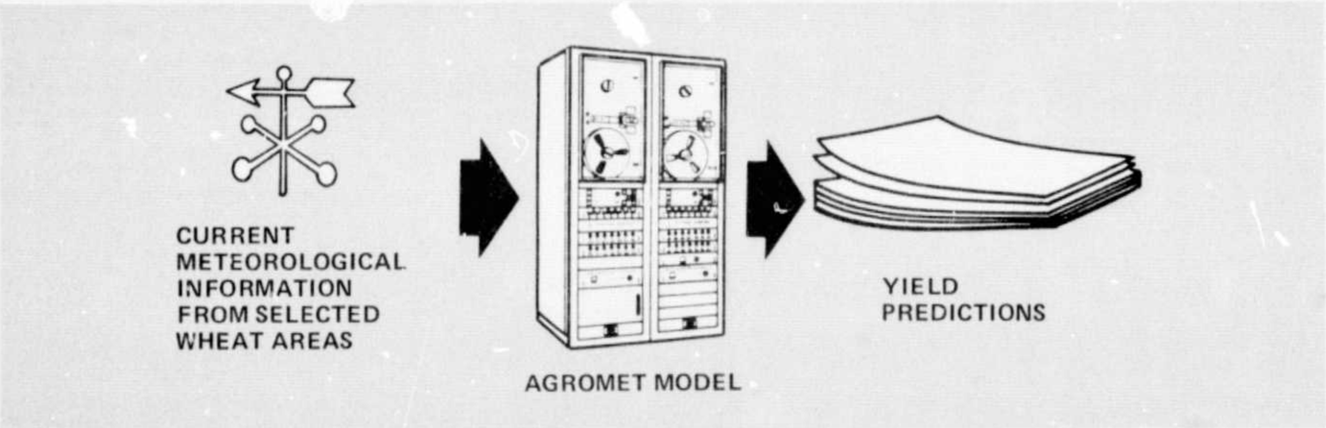
The automated analysis of Landsat images that is used to classify wheat and measure its acreage can also be used to evaluate the condition of wheat and other crops. Images of healthy, vigorous crops have different spectral signatures than do stressed or sparse crops. It is expected that multispectral images will also be used in crop yield estimates by revealing actual crop conditions.

At some time in the future, remote sensing techniques may provide a direct estimate of the yield of the crop being observed. Until those methods are developed, LACIE will estimate yields from the statistical models which use meteorological observations. Those agrometeorological models put numbers into the well-known fact that weather can be favorable or unfavorable for crops. For ex-

ample, the model estimates how many extra bushels of wheat might result from an extra inch of rain or how many bushels less might be expected from a certain number of degrees of temperature above the ideal for wheat during the growing period when the kernels are filling.

While weather affects the yield of wheat, it also influences the rate of growth of the plants. Mathematical formulas that use weather data to estimate the stage of wheat development on any given day are available. These models, called crop calendars, are very useful to the analysts who must review the Landsat images and label which fields are actually wheat. By watching the changing spectral signatures throughout the growing season and comparing them with the growth stage projected by the crop calendar, the wheat fields can be more accurately separated from the crops which develop differently, such as alfalfa, soybeans, or rice.

Too little or too much of either precipitation or temperature will cause wheat plants to produce less grain per acre.



An agromet model is a computerized mathematical model of how variations in temperature and rainfall affect the wheat yield per acre in selected areas. The amount of wheat harvested per acre (yield) in a given location depends on the weather. The computerized yield model predicts how current weather will affect the crop, based on how weather has affected crops in past years.

When will LACIE be completed?

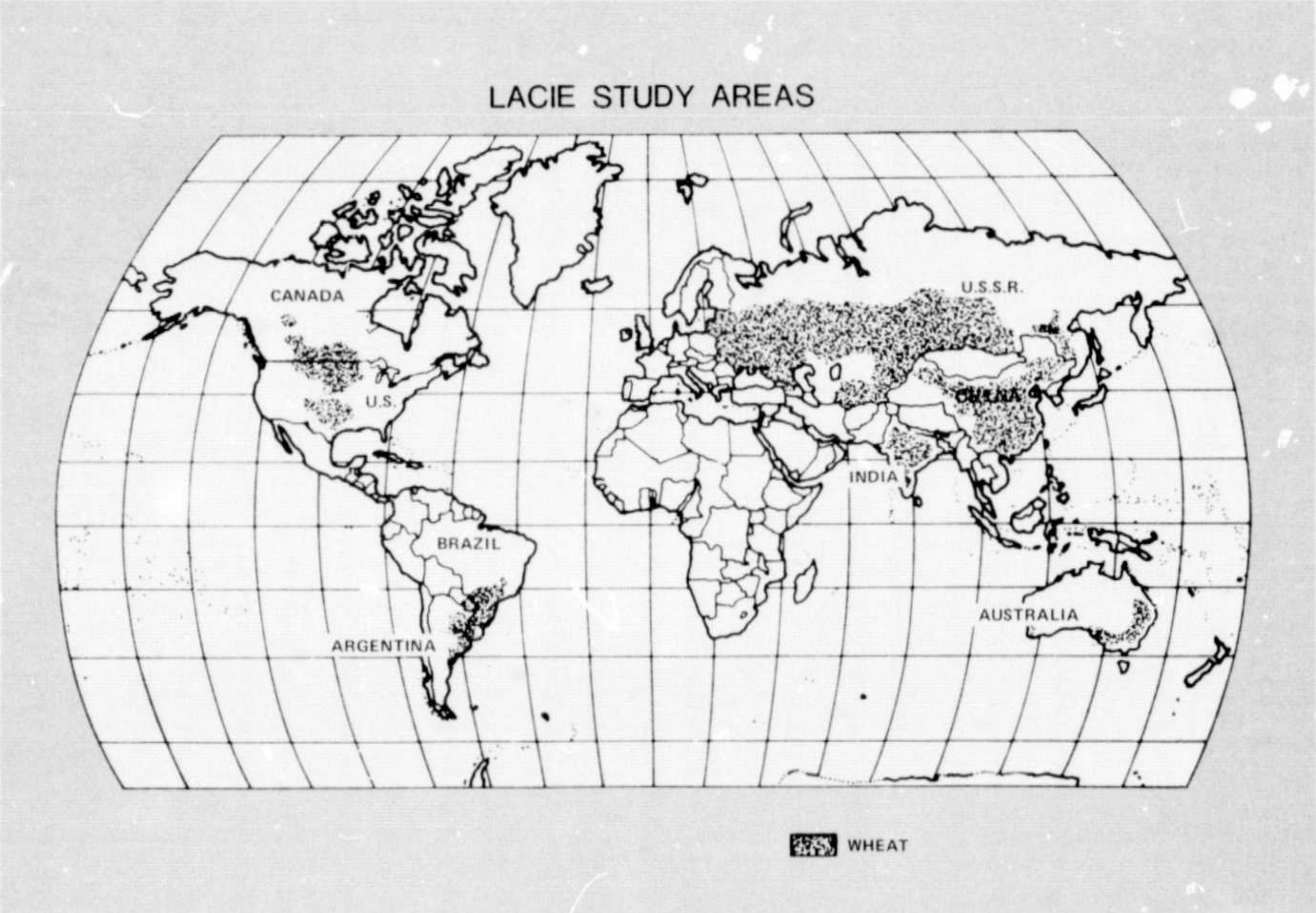
LACIE is being conducted in three phases, each tied to the wheat-growing cycle and expanding in scope as experience is gained.

In Phase I, 1974-1975, LACIE addressed area estimates for nine wheat-growing states in the U.S. Great Plains. Yield models were tested and production estimates were made. Computer classification of Landsat images of representative samples segments in other wheat-growing regions and several intensive test sites in North America were analyzed to provide a basis to assess LACIE performance.

In Phase II, fall 1975 to spring 1977, activities included wheat area, yield, and production estimates for the U.S. Great Plains, Canada, and parts of the U.S.S.R. Tests were continued on representative sites elsewhere in the Northern and Southern Hemispheres.

In Phase III, fall 1976 to spring 1978, LACIE provides area, yield, and production estimates over additional regions. Refinements in technology developed through research and gained from experience in earlier phases are incorporated.

Following Phase III, there will be a phase called LACIE Transition. It continues through spring of 1979 so that crop monitoring systems being developed by USDA can exploit LACIE technology. The USDA systems will be designed to estimate global wheat production and will be expanded later to include food and fiber products of many types on a worldwide basis.



What Next?

LACIE's success in predicting wheat production in test areas indicates that its technology will provide an efficient, cost-effective way to monitor agricultural activity. Any LACIE-developed techniques will be available to all who wish to use them, both in the United States and elsewhere.

USDA builds on LACIE to develop an operational subsystem of its data-gathering network; the production estimates that result will be available to the worldwide agricultural community.

With more timely and complete crop production estimates, all elements of agriculture could plan more efficiently and profitably. If key agricultural questions are answered more accurately, the resulting improvement in agricultural decisions could mean more profitable agricultural operations with more equitable prices to the consumer.

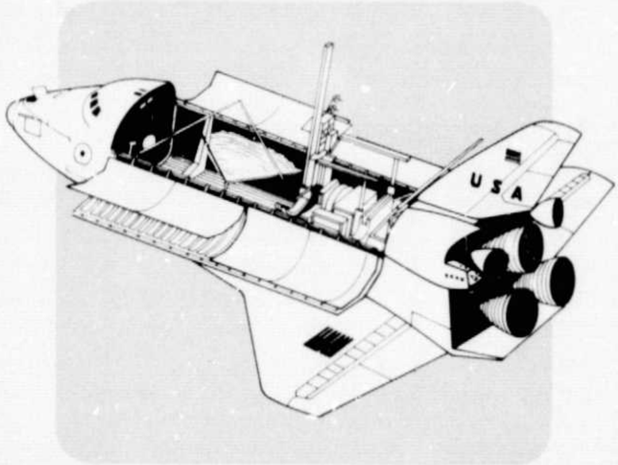
In the mid-1980's, "International trade of all types will have reached a new high, especially agricultural production and marketing will be widespread as the world seeks to maximize its ability to feed itself."[1]

There will be sufficient advances in technology and enough new satellites of improved design to provide sufficient data for an operational crop survey system. In addition, there will be an operational space shuttle and a fleet of high altitude aircraft to gather specialized data.

There will be an increasing use of large-scale data banks, computational capability, and analytical techniques by all sectors of the population, brought on by massive increases in computer power and domestic satellite data transmission. Computer analysis will have progressed so that dynamic modeling of crop production using remotely sensed input will no longer be thought of as an oddity.

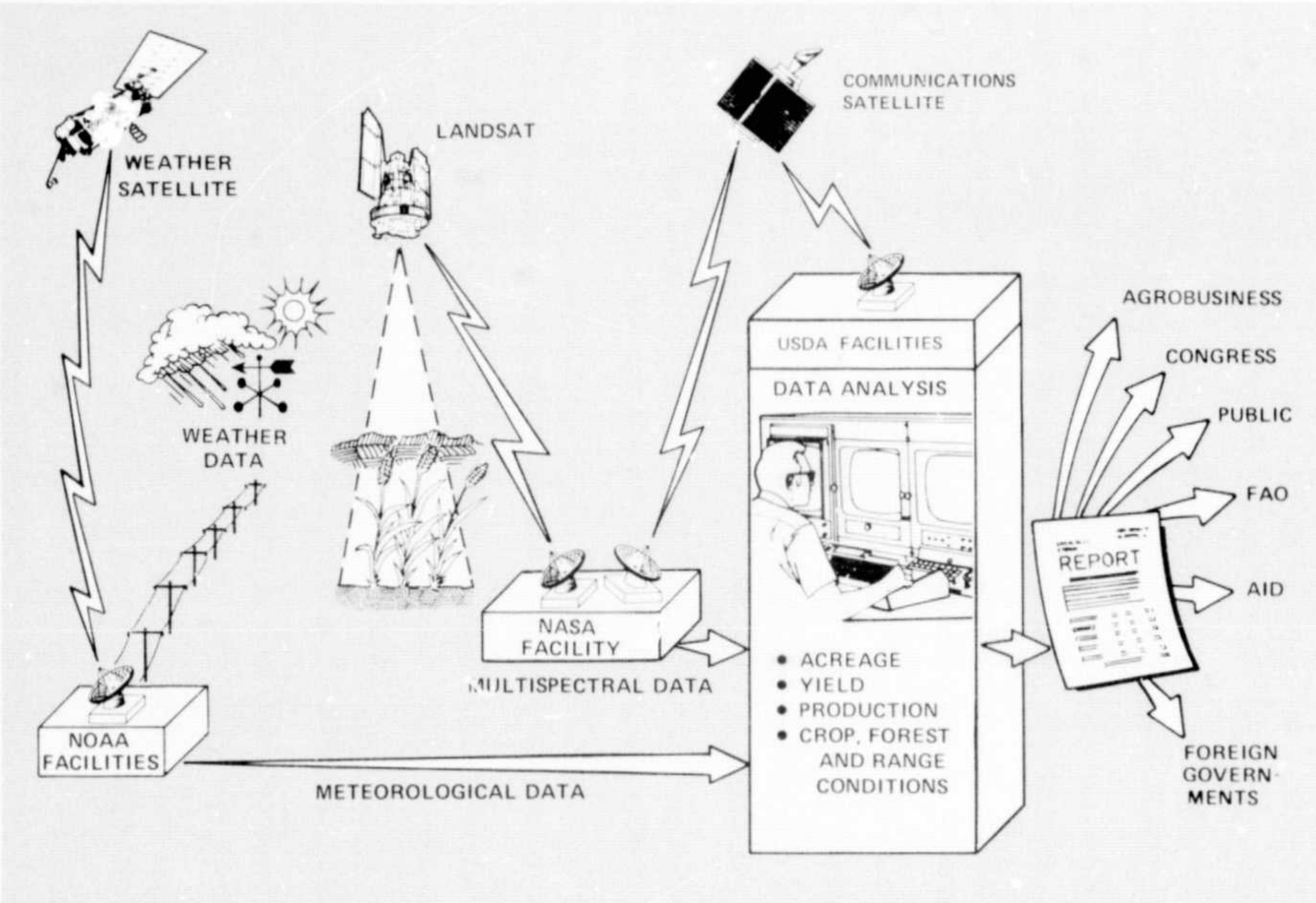
Through the 1980's, current techniques need to be further developed and adapted to use the powerful combination of satellite data collection and computer analysis to perform the survey of the following agricultural tasks on a global scale.

- Survey cropland to prepare statistical summaries and production forecasts for major crops.
- Monitor pasture and cropland to detect and assess insect, disease, and stress damage.
- Survey cropland to evaluate current farming practices and classify areas on the basis of productivity.
- Survey and monitor cropland to calculate short- and long-run demand for irrigation water.
- Survey major crops on a global basis to inventory acreage and forecast wheat production.
- Survey pasture and range areas to prepare statistical summaries of forage acreages, calculate supportive capacity for livestock, and assess current grazing practices.



Space Shuttle — Earth Observations Configuration

(1) From NASA Earth Resources Program Office publication entitled "Definition of the Total Resources System for the Shuttle Era."



System for inventory and monitoring global food and fiber. Information is passed to Agrobusiness, the U.S. Congress, the public, the Food and Agriculture Organization (FAO) of the United Nations, and the U.S. Agency for International Development (AID), and to foreign governments.